CARBONS, INC.

Lorraine Arc Carbons DIVISION ORLUX for the MOTION PICTURE INDUSTRY
ACTINA for the GRAPHIC ARTS INDUSTRY SOLAR for the ENVIRONMENTAL SCIENCES
XeTRON PRODUCTS DIVISION • LAMPHOUSES • POWER SUPPLIES • XENON BULBS

General Offices and Plant. BOONTON NEW JERSEY 07005 • Reply to P O BOX 217 • DEERFIELD 4 5500
CABLE ADDRESS "CARBONINC"

July 27, 1965

N.A.S.A. Manned Spacecraft Center
2101 Webster Seabrook Road
Houston 1, Texas 77058

SOLAR CARBONS

R & D CONTRACT NAS 9-3698

TRANSLATION

FINAL REPORT NO. 10

- CONTENTS -

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(Translation)

I - INTRODUCTION

A - SHELL, CORE, GLUE

10.0.1 The present report summarizes the different paths followed in the studies of the shell, core and glue.

10.0.2 With respect to the shell, the studies were oriented in order to avoid the breakage of shells either at the strike or during burning. On the other hand, we looked for methods for obtaining a straight edge on the crater to minimize the waviness of the rim of the crater (scalloping).

The reduction of the scalloping gives a greater regularity to the radiance of the crater.

10.0.3 With respect to the core the purpose of the study was to obtain regularity in the emission of the vapors. The vaporization of the minerals of the core must occur in a regular fashion in order to avoid projection of molten material, which produces pitting of the optical devices.

On the other hand, the carbon of the core must be combined as perfectly as possible with the mineral salts of the core also to reduce the pitting .

10.0.4 With respect to the glue, the purpose of the study was to insure a good binding between the core and the shell. This study is associated with the study of the clearance between the shell and the core and leads to a reduction of the scalloping.

B - JOINTS

10.0.5 We summarized the tests made on the joints. Although this study was not part of the contract, we felt it desirable to examine the means of insuring the passage from one electrode to the following, with the minimum of disturbances.

C - DISTRIBUTION OF THE SPECTRAL ENERGY

10.0.6 In the present report, we give the spectral energy distribution of the 16 mm diameter positive electrode, giving the very best burning performance.

II - TEST OF SHELLS

10.0.7 On figure 10.1 which appears at the end of this chapter, we assembled and coordinated all the studies made on the shell, starting from the original formula 8764. This chart gives the logical lineage and classification of the different formulas that were tested. We started with the principle that any formula is derived from a previous parent formula.

However, it is obvious that when a new formula is established, several factors can be modified at the same time and consequently a given formula may be derived from several previous formulas.

In establishing the chart of figure 10.1, we chose as the parent formula the one which presented the minimum variation with the formula under study.

10.0.8 Using dotted lines, we showed certain influences or similarities which could exist between two formulas, although these formulas were not actually derived from each other. This case occurs, for instance, when we take into account some results obtained in a line of research which was abandoned in order to pursue the research in another direction. This also occurs in the series of tests of systematical and comparative character, such as for 8812, 8816, 8823, 8819.

10.0.9 Finally, we completed the chart by indicating the nature of the change with a code number, which allows us to change from one formula to the other. This code is given in the annex to chart No. 1 (figure 10.2). For instance, we change from 8852 to 8853 with operation 42, which means that we increase the amount of fraction A of the coking agent.

10.10 Annex 2 to chart No. 1, (figure 10.3) gives the list of the formulas which were tested and the reference numbers of the reports and paragraphs where these formulas were studied.

We did not indicate in this chart the preliminary studies made around the basic formula 8764 at the start of our program, the results of which were given in Reports No. 1 and 2. These are the three abandoned formulas:

8763 - paragraph 1.3.1.1

8759 - paragraph 1.3.1.2

1687 - paragraph 2.5.3 to 2.6.0

10.11 The chart of figure 10.1, summarizes the study made on the shell during this contract. However, we feel that it should be supplemented with a short listing of the main points of our study.

A - VARIATION OF THE NATURE, GRANULOMETRY AND AMOUNT OF ARTIFICIAL GRAPHITE.

10.12 Of all these variations, the change of the nature of graphite was the most interesting. The use of G.P 9 graphite allowed us to obtain a shell with better physical characteristics and a much lower scalloping index. Therefore, the final formula decided upon at the end of the contract is based on graphite G.P 9.

The use of a greater percentage of graphite or of a graphite with coarser granulometry did not bring any noticeable improvement.

B - INFLUENCE OF THE COKE BASE PRIMARY 1934

10.13 The amount of this primary can be reduced without causing any trouble. However, a certain amount should be included in order to insure the stability of the formula. This is especially true for formulas with a medium amount of lamp black.

C - INCREASE OF THE AMOUNT AND INFLUENCE OF THE NATURE OF LAMP BLACK

10.14 This study showed us that the shells with a medium amount of lamp black (about 30 % of the weight of powders) were more advantageous. They had good transverse strengths and greater brightness. However, the burning rate is slightly higher than for the shells with a smaller amount of lamp black.

Nevertheless, the results obtained to date were insufficient to contemplate a transposition to the industrial level and this direction of research would require additional study.

We also saw that the nature of the lamp black had some influence on the physical characteristics.

- OPTIMUM PERCENTAGE OF FRACTION "A" OF THE COKING AGENT

10.15 The study showed that the optimum percentage was 7 % and that this value was interesting chiefly with formulas having a medium amount of lamp black.

Under these conditions, we found a definite improvement of the physical characteristics. However, it must be noted that the performance of the shell in the arc seems practically independent of fraction "A" of the coking agent.

Therefore, we finally kept the percentage at 5 % in formula 8848, chosen at the end of this contract.

E - PERCENTAGE OF FRACTION "B" of COKING AGENT

10.16 In this matter, the study was profitable. It showed that it was advantageous to eliminate these additives. Without any modification of the physical characteristics, the elimination of fraction "B" improves the brightness of the carbon and slightly decreases the scalloping index.

Consequently, we eliminated fraction "B" of the coking agent, in the formula chosen at the end of this study.

F - USE OF A TAR OTHER THAN 78/22

10.17 Several times during our research, we used a tar 90/10. This substitution gave somewhat better physical characteristics but, for all practical purposes, did not influence the performance of the carbon in the arc. Therefore, we do not believe that the change should be made.

G - SIMPLIFICATION OF THE PREPARATION PROCESS

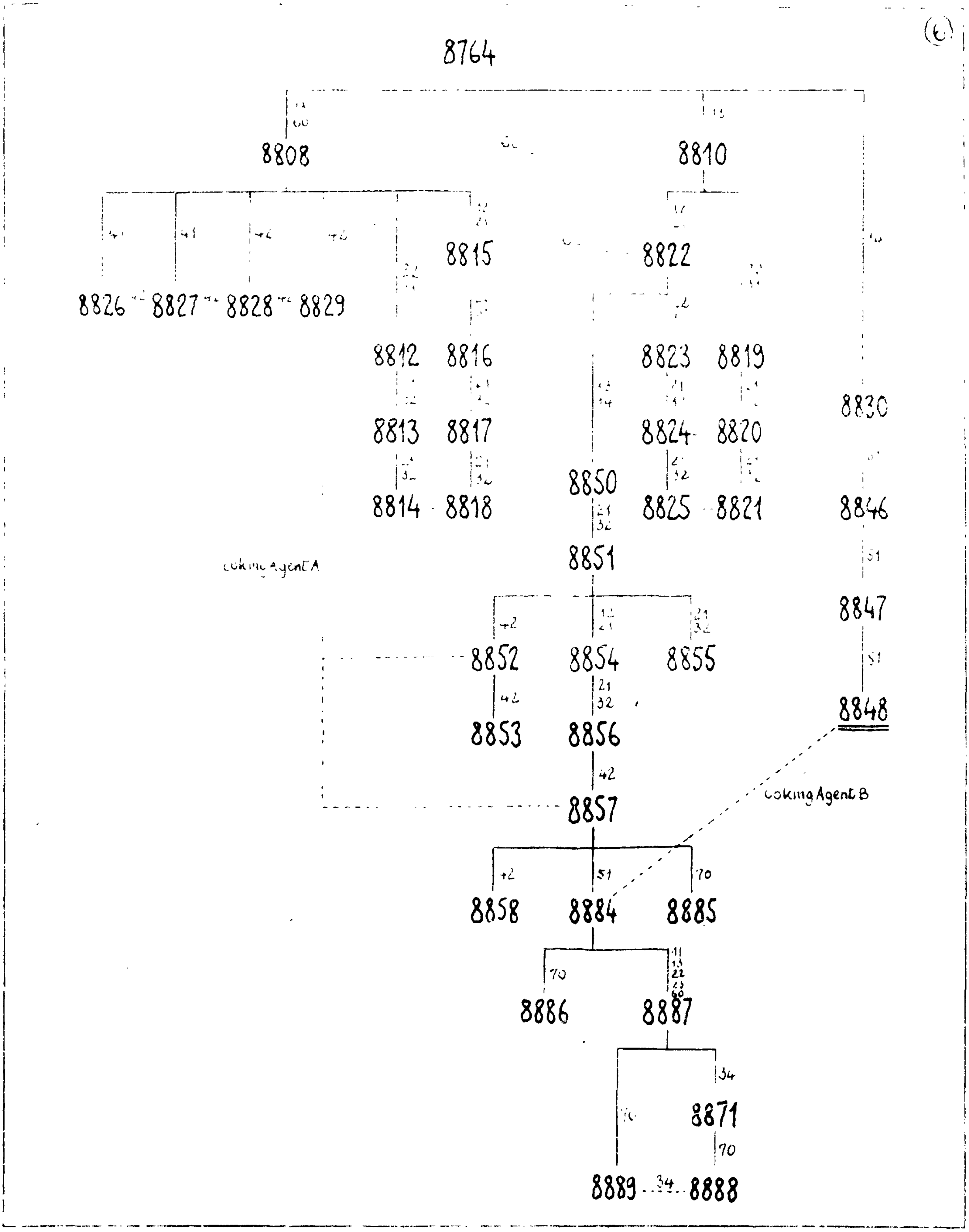
10.18 We found that simplification was not desirable and that the T.M. technique should be continued.

10.19 Summarizing, this study showed the great advantage of the composition of the starting formula 8764, that is:

Artificial graphite	60 %
Primary 1934	30 %
Lamp black	10 %

The study brought a certain number of improvements and finalized a much improved formula 8848 which we decided to keep.

On the other hand these tests opened new directions of research which seem interesting but they require a more thorough study for their correct evaluation.


8764
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coking Agent B
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Figure 10-2

ANNEX 1 - CODE OF THE OPERATIONS MADE ON THE SHELL DURING THE STUDY

Operations on	Code	Nature of operation
- artificial graphite	11	Decrease amount
	12	Increase amount
	13	Change granulometry
	14	Change nature
- coke base primary 1934	21	Decrease amount
	22	Increase amount
	23	Change granulometry
- lamp black	31	Decrease amount
	32	Increase amount
	34	Change nature
- fraction "A" of coking agent	41	Decrease amount
	42	Increase amount
- fraction "B" of coking agent	51	Decrease amount
- tar	60	Change nature
- process	70	Simplification of the technique using a direct process

Figure 10-3

ANNEX 2 - INDEX OF THE SHELL FORMULAS COVERED BY THE STUDY

8864	Report No. 1	paragraphs	1.3.10	to 1.3.15
	No. 2		2.3.3	
8808	Report No. 2	paragraphs	2.4.4	to 2.5.2
	No. 3		3.1.3	to 3.5.2
	No. 4		4.0.7	to 4.0.9
	No. 4		4.1.1	to 4.3.1
8810	No. 2		2.4.7	to 2.5.2
	No. 3		3.1.3	to 3.5.2
	No. 4		4.0.7	to 4.0.9
8812, 8813, 8814, 8815, 8816, 8817, 8818, 8819, 8820, 8821	No. 3		3.1.3	to 3.5.2
	No. 4		4.0.7	to 4.0.9
8822	No. 3		3.1.3	to 3.5.2
	No. 4		4.0.7	to 4.0.9
	No. 6		6.1.2	to 6.2.7
8823, 8824, 8825	No. 3		3.1.3	to 3.5.2
	No. 4		4.0.7	to 4.0.9
8826, 8827, 8828, 8829	No. 4		4.1.1	to 4.3.1

Figure 10-3 (continued)

8830	)	Report No. 5	paragraphs	5.0.5	to	5.1.8
8846	( )	No. 6		6.0.8	to	6.1.1
8847	(					
8848		Report No. 5		5.0.5	to	5.1.8
		No. 6		6.0.8	to	6.1.1
		No. 7		7.0.3	to	7.0.9
			and	7.1.6	to	7.1.9
		Report No. 8		8.0.3		
		No. 9		9.0.8	to	9.2.1
8850	)					
8851	( )					
8852	(					
8853	) (	Report No. 6		6.1.2	to	6.2.7
8854	)					
8855	( )					
8856	(					
8857		Report No. 6		6.1.2	to	6.2.7
		No. 7		(7.0.3	to	7.0.8
				)7.1.0	to	7.1.1
				(7.1.6	to	7.1.7
		No. 8		8.0.4	to	8.2.7
8858		Report No. 6		6.1.2	to	6.2.7
8871		Report No. 8		8.0.4	to	8.2.7
		No. 9		9.0.8	to	9.2.1
8884		Report No. 7		(7.0.3	to	7.0.8
				)7.1.2	to	7.1.5
				(7.1.6	to	7.1.7
		Report No. 8		8.0.4	to	8.2.7
8885		Report No. 8		8.0.4	to	8.2.7
8886		No. 8		8.0.4	to	8.2.7
8887		No. 8		8.0.4	to	8.2.7
		No. 9		9.0.8	to	9.2.1
8888		Report No. 8		8.0.4	to	8.2.7
8889		Report No. 8		8.0.4	to	8.2.7

III - TESTS OF CORES

10.20 All the studies made on the core, starting with the parent formula 290, were assembled and coordinated on the chart attached at the end of this chapter (figure 10.4). This charg gives the logical lineage and classification of all the formulas that were tested.

As for the shell, we chose as the parent formula, the one that had the minimum of variation with the formula under study.

10.21 The dotted lines emphasize the influences or similarities which could exist between two formulas, although they are not derived from each other. Some results secured in one direction (later abandoned) were taken in account to pursue the research in another direction.

10.22 To emphasize in the chart the variations between formulas, we coded the various changes that were made. On the line connecting a parent formula to a derived formula, the code (s) shows the transformation(s) made in going from one formula to another. This code is given in annex No. 1 to the chart (figure 10.5).

10.23 Finally, in annex 2 (figure 10.6) the list of the formulas tested is referenced with relation to the report number and paragraphs where these formulas were studied.

10.24 Chart 10.4 completely summarizes the study made on the core during the contract. However, we feel it necessary to supplement it with a short listing of the different points of our study and conclusions.

These points are enumerated in the chronological order of the study.

A - KEEPING THE AMOUNT OF CERIUM CONSTANT , we studied the influence of:

10.25
- the decrease in the amount of strontium and iron,
- the decrease in the amount of strontium and the increase of fluorine.

This study made on formulas 307, 308, 309, 310, 311 and 312 showed that the increase of cerium fluoride in the core could increase the pitting. The amount of cerium fluoride contained in formula 290 appeared as a maximum not to be exceeded.

B - INFLUENCE OF TRITURATION ON FORMULA 290

10.26 The study made on formulas 313, 314, 315, 316, 317, 318 and 319 showed that in the case of core 290, the maximum trituration gave the minimum pitting. We also found that prior working of powders in the tumbling mixer was unnecessary and that, in certain cases, it was even detrimental. Once this was established, we eliminated the operation. Therefore, starting with formula 324, the formulas that were tested did not include the use of the tumbling mixer any more.

C - DECREASE IN THE AMOUNT OF STRONTIUM AND CERIUM BY MODIFICATION OF THE AMOUNT OF CERIUM FLUORIDE

10.27 This study was made with formulas 320, 321 and 322 (see Report No. 5 paragraph 5.2.6), and showed that the decrease of the amount of strontium reduced the pitting and that we should keep the amount to a minimum. On the other hand, the decrease of the amount of cerium seems advantageous, however, it should not be done by reducing the amount of cerium fluoride.

D - DECREASE IN THE AMOUNT OF CERIUM BY USING CERIUM OXIDE

10.28 This study was made with formulas 328, 329 and 330 and brought a noticeable decrease of the pitting.

Formula 330 was kept as the parent formula for the continuation of the tests, starting with formula 335, although it showed a rather low transverse strength. It should be noted, that following the conclusion of the study mentioned in paragraph C, formula 330 was made with the minimum amount of strontium.

E - REPLACEMENT OF STRONTIUM FLUORIDE BY CALCIUM FLUORIDE

10.29 This substitution, made with formulas 325, 326, 327 is not advantageous.

F - STUDY OF THE POROSITY OF THE CORE

10.30 Study was made with formulas 331, 332, 333 and 334. We obtained porous cores which were no better than the previous ones, with respect to pitting. They also have the disadvantage of a very poor transverse strength. We therefore abandoned this direction of research.

G - INFLUENCE OF THE GRANULOMETRY OF CERIUM FLUORIDE

10.31 This study was made chiefly with formula 335 and with formulas 336 to 340 and 343 to 354.

The granulometry of the cerium fluoride has no influence on the pitting and therefore, there is no reason to change it. That is why in formula 356, we came back to the initial granulometry.

H - INFLUENCE OF THE MIXING TECHNIQUE (use of the "Y" mixer or inertia mixer)

10.32 The study was made with formulas 338 and 339. No improvement was recorded and therefore the idea was abandoned.

I - INFLUENCE OF CERIUM OXIDE BASE PRIMARIES

10.33 Made with formulas 336, 337, 340, 343, 348, 352, 353, 354 and 374, this study showed the advantages of primary 7082 for the present manufacture. However, primary 7290 with graphite showed a tendency to give better results and formula 374 showed that additional studies would be desirable.

J - AGGLOMERATION WITH TARS OTHER THAN 90/10

10.34 Study was made with formulas 333, 334, 345, 346 and 347, and showed that the use of a lighter tar gave a more porous core but decreased the transverse strength, and to a certain degree, increased the pitting.

To increase the transverse strength and decrease the pitting with the use of a light tar, it is necessary to use a higher amount of fraction "A" of the coking agent.

K - INFLUENCE OF FRACTION "A" OF THE COKING AGENT ON THE FORMULAS WITH TAR BASE

10.35 A study was made with formulas 340, 345, 346 and 347. The increase of fraction "A" of the coking agent seemed to slightly decrease the pitting, at the same time improving the transverse strength of the core.

L - INTRODUCTION OF LAMP BLACK IN THE CORE

10.36 This was made with formulas 344 to 354, 372, 373 and 379, and is advantageous with respect to the pitting. However, it is premature to draw a definite conclusion and additional studies on this point would be desirable, as the previous one.

M - VARIATION OF THE GRANULOMETRY OF FLAKE NATURAL GRAPHITE

10.37 This study was made with formulas 318, 349 and 350. No appreciable improvement was recorded and the idea was dropped.

N - AGGLOMERATION WITH BAKELITE

10.38 The study was made with formulas 323, 343, 356, 372, 373, 374 and 379.

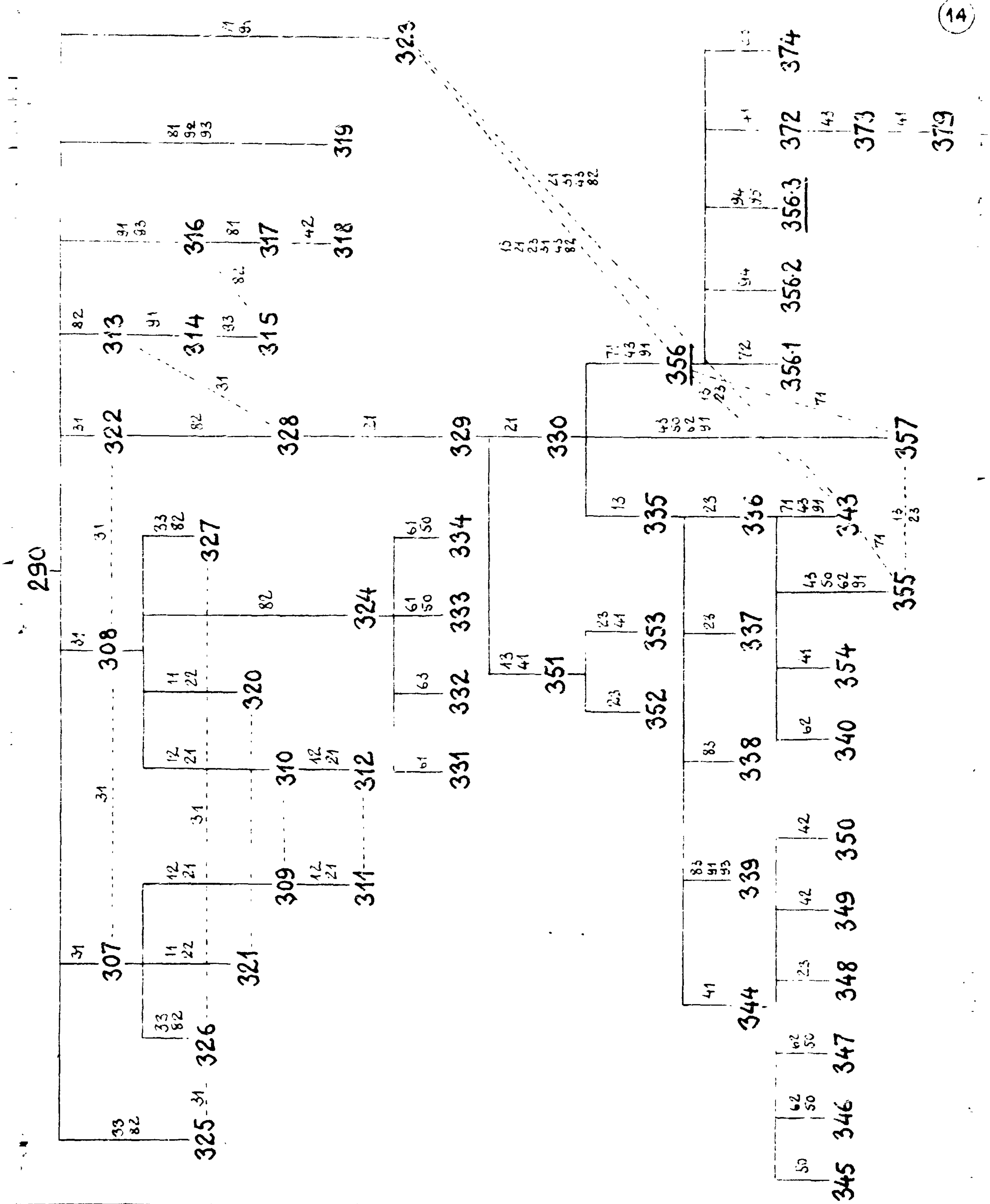
This is the change which, by far, gave us the greatest improvement. We had a hint of the advantage of the change with formula 323 using flake natural graphite. However, it was impossible to pursue this formula because agglomeration of the flake natural graphite with Bakelite is extremely difficult, even with the addition of lamp black (formulas 373 and 379).

Following this, we replaced flake natural graphite with artificial graphite. We then had the first very interesting formula: 343. However, this formula had cerium fluoride with granulometry 300 and primary 7291. A parallel study showed very little advantage of these elements and we came back to cerium fluoride 100 and primary 7082.

We then obtained formula 356 which we finally kept and which was transposed successfully to the industrial level (formulas 356-1, 356-2 and 356-3).

With formulas 355 and 357 we demonstrated that the spectacular improvement was due to the use of Bakelite.

Finally we verified that with Bakelite as an agglomerant, the advantages of primary 7290 (formula 374) and the addition of lamp black (formula 373) were confirmed.



Société Le Carbone Lorraine

Laboratoire de Pagny-sur-Moselle

REPORT n° 10 Fig 10

Jul. 27. 1965

Figure 10-5

ANNEX 1 - CODE OF THE OPERATIONS MADE ON THE CORE DURING THE STUDY

Operations on	Code	Nature of operation
- cerium fluoride	11	Decrease amount
	12	Increase amount
	13	Change granulometry
- the primary used for introducing cerium oxide	21	Decrease amount
	22	Increase amount
	23	Change of primary
- strontium fluoride	31	Decrease amount
	32	Increase amount
	33	Replacement by calcium fluoride
- carbonaceous filler	41	Introduction of lamp black or increase of amount in a formula already containing lamp black
	42	Change of the granulometry of flake natural graphite
	43	Replacement of flake natural graphite by artificial graphite 200 and vice-versa
- tar	50	Change type of tar
- various agents:		
- fraction "A" of the coking agent	61	Decrease amount or elimination
	62	Increase amount
- porosity agent	63	Addition
- Bakelite	71	Replacement of tar and fraction "A" of coking agent with Bakelite or vice-versa
	72	Modification of amount
- preparation of powders	81	Special treatment with tumbling mixer
	82	Elimination tumbling mixer
	83	Mixing with inertia mixer ("Y" type)
- preparation of mix	91	Elimination of mixing with mixing rolls
	92	Elimination of first mixing
	93	Elimination of first extrusion and second mixing
	94	Modification of characteristics of first extrusion
	95	Addition of a third extrusion

Figure 10-6

ANNEX 2 - INDEX OF THE CORE FORMULAS WHICH HAVE BEEN STUDIED.

290	Report No. 1	paragraphs	1.2.2		
307	Report No. 2	paragraphs	2.6.1	to	2.7.5
	Report No. 5	paragraph	5.2.6		
308	Report No. 2	paragraphs	2.6.1	to	2.7.5
	Report No. 5	paragraph	5.2.6		
309	Report No. 2	paragraphs	2.6.1	to	2.7.5
310	"	"	"		"
311	"	"	"		"
312	"	"	"		"
313	Report No. 4	paragraphs	4.3.5	to	4.5.1
	Report No. 6	paragraphs	6.2.9	to	6.3.6
314	Report No. 4	paragraphs	4.3.5	to	4.5.1
315	"	"	"		"
316	"	"	"		"
317	"	"	"		"
318	"	"	"		"
319	"	"	"		"
320	Report No. 5	paragraphs	5.2.6	to	5.3.7
321	"	"	"		"
322	"	"	"		"
323	"	paragraphs	5.3.8	to	5.4.2
324	Report No. 7	paragraphs	7.3.5	to	7.3.7
325	"	"	"		"
326	"	"	"		"
327	"	"	"		"
328	"	paragraphs	7.4.2	to	7.4.9
329	"	"	"		"
	Report No. 8	paragraphs	8.3.0	to	8.4.6
330	Report No. 7	paragraphs	7.4.2	to	7.4.9
	Report No. 8	paragraphs	8.3.0	to	8.4.6
331	Report No. 7	paragraphs	7.5.0	to	7.5.4
332	"	"	"		"
333	"	"	"		"
334	"	"	"		"

Figure 10-6

335	Report No.	8	paragraphs	8.3.4	and	8.3.5
336	"		paragraphs	8.4.0	to	8.4.6
337	"		"		"	
338	"		paragraphs	8.3.6	to	8.3.9
339	"		"		"	
340	"		paragraphs	8.4.9	to	8.5.3
343	"		paragraphs	8.6.0	to	8.6.4
	Report No.	9	paragraphs	9.2.9	to	9.4.4
344	Report No.	8	paragraphs	8.4.7	and	8.5.5 to 8.5.8
345	"		paragraphs	8.4.7,	8.5.3,	8.5.5 to 8.5.8
346	"		paragraphs	8.4.9	to	8.5.3
			and	8.5.5	to	8.5.8
347	"		paragraphs	8.5.5	to	8.5.8
348	"		paragraphs	8.4.2	to	8.4.6
			and	8.5.5	to	8.5.8
349	"		paragraphs	8.5.5	to	8.5.9
350	"		"		"	
351	"		paragraphs	8.5.5	to	8.5.8
352	"		paragraphs	8.4.2	to	8.4.6
			and	8.5.5	to	8.5.8
353	"		paragraphs	8.5.5	to	8.5.8
354	"		"		"	
355	Report No.	9	paragraphs	9.2.9	to	9.4.4
356	"		"		"	
356-1	"		paragraphs	9.4.6	to	9.5.2
			and	9.5.4	to	9.6.1
356-2	"		paragraphs	9.5.4	to	9.6.1
356-3	"		paragraphs	9.5.4	to	9.6.1
357	"		paragraphs	9.2.9	to	9.4.4
372	"		paragraphs	9.6.3	to	9.7.1
373	"		"		"	
374	"		"		"	
379	"		"		"	

IV - STUDY OF THE CLEARANCE AND GLUE BETWEEN SHELL AND CORE

A - STUDY OF THE CLEARANCE

10.39 When we started the study for the improvement of the 16 mm diameter positive electrode, we found that with the elements used at that time, the minimum clearance between core and shell had to be 0.15 mm (Report No. 1, paragraph 1.1.6).

10.40 The tests which followed were made with a clearance greater than 0.15 mm. But we found that with a clearance greater than 0.20 mm, it was difficult to secure a consistent gluing and a correct centering of the core in the shell. (Report No. 5 paragraph 5.4.4).

10.41 When we proceeded with the study of different glues, positive electrodes were made with clearances of 0.10 mm, 0.15 mm and 0.20 mm. We found that with a clearance less than 0.10 mm it was practically impossible to introduce the core into the shell (Report No. 6, paragraph 6.3.7).

10.42 We again started the study of the clearance when we arrived at formula 356, which was particularly advantageous with respect to pitting. We concluded that with shell 8848 and core 356, the clearance should be between 0.15 and 0.20 mm (Report No. 9, paragraphs 9.9.2 and 9.9.3).

B - STUDY OF THE GLUE

10.43 The glue used at the beginning of this study was glue 2848. This glue, which we used at the production level for positive electrodes including a solid core, is made of a mineral binder with a coke flour filler (Report No. 6 paragraphs 6.3.7 and 6.3.8).

10.44 We studied the use of other glues using different carbonaceous fillers or without any filler. We particularly explored the:

- Chemical nature of the glue:
  - mineral binder
  - thermosetting resin
  - tar

- Nature of the fillers incorporated in the glue:
  - coke flour
  - lamp black
  - charcoal

(Report No. 6, paragraphs 6.3.7 to 6.3.9)

10.45 - Glues with mineral binder (Report No. 6, paragraph 6.4.1)

4024	without filler	(paragraph 6.5.2)	abandoned
2848	with coke flour	(paragraph 6.5.3)	chosen
2954	with lamp black	(paragraph 6.4.1)	abandoned
2956	with charcoal	(paragraph 6.5.1)	abandoned

10.46 - Glues with thermosetting resins (Report No. 6 paragraphs 6.4.2 and 6.4.0).

2953	without filler	(paragraph 6.5.2)	abandoned
2952	with lamp black	(paragraph 6.4.6)	abandoned
2955	with charcoal	(paragraph 6.5.1)	abandoned

10.47 - Glues with tar (Report No. 6 ,paragraph 6.4.3)

2957	without filler	(paragraph 6.5.0)	abandoned
2958	with lamp black	(paragraph 6.5.0)	abandoned

10.48 The results of performance in the arc regarding these various glues were given in figures 11, 12 and 13 or Report No. 6.

10.49 Concluding this study, we kept glue 2848 for the manufacture of the positive electrode with shell 8848 and core 356 (Report No. 9, paragraphs 9.8.8 and 9.9.3)

V - <u>STUDY OF THE JOINTS BETWEEN CARBONS</u>

10.50 We studied several means of jointing the 16 mm diameter positive electrode. The New Technology Clause report of June 11, 1965, gave the results obtained with several types of joints that were made:

	paragraph		
- Joints using the shell	1.0.5	to	1.0.6
- Composite joints using shell & core	1.0.7	to	1.1.7
- Joints using a shell	1.1.8	to	1.2.0
- Conical joints, shell and core	1.2.1	to	1.2.4
- Conical joints with core only	1.2.5	to	1.3.2

10.51 We kept the type of conical joint with core only. This joint is the one that insures the very best conditions of passing from one positive electrode to the following. It is with this joint that we obtained the minimum duration of disturbance and the smallest variation of light output when the joint goes through the arc.

Blueprint No. 1008, attached, shows this joint. There are 22 rounded threads per inch.

VI - MANUFACTURING PROCESSES AND CONTROL PROCESSES FOR THE SHELL

10.52 The formula that we kept for the manufacture of the shell of the 16 mm diameter positive electrodes (Report No. 7 paragraphs 7.0.9 and 7.1.8 - Report No. 9, paragraph 9.7.5) is formula 8848. We give below:

- a description of the manufacturing processes of the shell,
- the different controls that we apply to the raw materials and the finished shells in order to secure constant quality.

A - DESCRIPTION OF THE MANUFACTURING PROCESS

10.53 The mix is made in a mixer of the Werner type, which is a kneader type with blades. The different powders comprising the mix are weighed separately before being poured into the machine.

The tar is spread in the mixer during the mixing operation and the mix so obtained continues to be kneaded for a certain period of time in the mixer.

After the mixing, the batch goes through several operations of intensive trituration: a mixing with a muller mixer, an extrusion and a second mixing.

10.54 The mix is then extruded in its definitive shape, taking into account the shrinkage during the kilning. The kilning, during which the coking of the agglomerant will occur, is made in a continuous ring furnace with many chambers.

After kilning, the shells go through a very rigorous control, which will be described later, and then machined to the dimensions of the finished electrode.

B - CONTROLS

B.1 - Control of the raw materials

10.55 The different raw materials comprising the mixes go through a certain number of quality controls before being used.

a) Carbonaceous Powders

10.56 Upon arrival at the plant, the raw materials are sampled at random and the following is measured:

- humidity
- volatile matter index
- ash content

The raw materials are thereafter milled and the powders are sampled at random for their granulometric analysis. If the granulometry is correct, the milled products are then stocked and ready for use.

b) Tar

10.57 The subject of the tar was covered at length in our Report No. 2 paragraphs 2.1.6 to 2.2.6 and will not be repeated.

Let us only repeat that the tar used to make shell 8848 is a tar 78/22, fluidity of which must be between 400 and 480 (Report No. 2 paragraph 2.1.5). The tar is prepared in great quantities and stocked in tanks. Before use, the fluidity is checked for the proper value.

B.2 - Control of the shells

10.58 a) After kilning, the shells are random sampled and the physical characteristics (density, electrical resistivity and transverse strength) as well as the performance in the arc, are checked.

The shells are accepted when the physical characteristics are in agreement with the specifications given by our laboratory and when their performance in the arc is satisfactory.

10.59 b) At this time, all the shells are sorted individually. The control covers the following points:

- the structure of the shell: all shells that have fissures are eliminated,
- the bow: all twisted shells are eliminated,
- the diameter of the hole: the shells are sorted by category, according to the diameter of the hole,
- the external diameter, after machining of the shell.

The quality of the sorting itself is controlled by random sampling in each batch of sorted shells.

10.60 c) Finally, when the electrodes are completely finished, they are again individually sorted. The sorting itself is checked by a random sampling and completed with a test in the arc utilizing a certain percentage of the production output.

Therefore we verify that all the performance characteristics are in agreement with the Standards required by the customer.

VII - PROCESSES OF MANUFACTURE AND CONTROL OF THE CORE

10.61 The formula chosen for the manufacture of the cores of the 16 mm diam. Solar Simulation carbons is formula 356-3 (Report No. 9, paragraphs 9.5.3 to 9.6.1 and 9.7.3).

As anticipated in our Report No. 9, the transposition of the variation of formula 356 to the industrial level was successful. We give below:

- a description of the manufacturing process of this core,
- the various controls with which we check the raw material and the finished cores in order to insure the consistency of their quality.

Remarks:

The manufacturing method which was outlined is valid for quantities of approximately 1000 pieces (that is for the supply connected with the present contract). For greater quantities, it will be necessary to use larger equipment, which certainly will require modifications to the manufacturing method.

A - DESCRIPTION OF THE MANUFACTURING PROCESS

10.62 a) The mix is made in a mixer of the Werner type, which is a kneader with blades. The various powders of the batch are weighed separately before being introduced into the machine. The Bakelite is added during the mixing operation and the mix continues to be kneaded for a certain period of time.

10.63 b) After mixing, the mix is thoroughly triturated through a succession of mixings and extrusions. It is then extruded to its final size, taking in account the shrinkage which will occur during the baking.

10.64 c) The baking begins with a polymerization which is made at a temperature less than 100° C for twelve hours. Then the agglomerant is coked in a continuous ring furnace, similarly to the shells.

10.65 d) After going through the controls, which will be mentioned later, the cores must be ground to the proper diameter before being glued into the shells.

B - CONTROLS

B.1 - Control of the raw materials

10.66 The various materials constituting the cores are carefully random sampled and analyzed.

For the mineral materials there is a chemical analysis and a granulometric control.

For the carbonaceous materials, we control the :

- humidity,
- volatile index
- ash content
- granulometry

Finally, for the Bakelite, we measure the viscosity and the ability to mix with water.

B.2 - Control of the cores

10.67 a) As soon as they are out of the kiln, the cores are sampled at random and the mechanical characteristics and the performance in the arc are checked.

Particular importance is given to the measurement of pitting.

Each mix makes a batch that can be used for the manufacture of electrodes, only if the sampling has given the proper results.

10.68 b) When the lot has been accepted, the acceptable cores are ground to the proper diameter and are individually sorted.

We examine the:

- structure (the fissured cores are eliminated)
- straightness (twisted cores are eliminated).

The cores are then glued in shells of adequate diameter and the electrodes go through a final control, which was indicated above (paragraph 10.60).

VIII - MANUFACTURING PROCESS OF THE GLUE USED BETWEEN SHELL AND CORE

10.69 The glue which was chosen is 2848 (Report No. 6, paragraphs 6.3.8, 6.4.1, and 6.5.3 - Report No. 9, paragraph 9.9.3).

It is prepared in the following manner: At the time of use the necessary amount of concentrated solution is poured in a vessel and the coke flour is added. The mixture is allowed to stand for one hour without stirring. At that point, the coke flour disperses in the mix without lumps.

The glue is then shaken in order to homogenize it. The glue so prepared can be used immediately. It can be kept for a few days provided it is kept from the air.

We do not have any special control of this glue, other than a density measurement of the concentrated solution of the mineral binder, at the time it is received.

IX - FINAL CONTROL OF THE ELECTRODES IN THE ARC LAMP

A - ACTUAL CONDITIONS OF THE BURNING TESTS

10.70 The burning tests of the 16 mm diam. positive electrodes are made in an RCA type burner, built at the Pagny laboratory. Two independent motors with reducing gears control the movement of rotation and advance of the positive electrode. This allows us to obtain the desired speed of rotation and to maintain the crater of the positive electrode in its position.

The RCA type burner is mounted so that, normally, all the burning tests are made with the axis of the positive electrode horizontal. However, if necessary, the device allows us to place the electrode axis vertically, the crater being oriented downwards.

10.71 The direct current is produced by a motor generator group. The generator is the shunt characteristic type; it is able to normally produce 400 amperes at 120 volts. To make the burning tests, a low value resistor (the ballast) is inserted in the arc circuit.

10.72 The conditions of operation were indicated in Reports 4 to No. 9 (paragraph 4.0.6, paragraph 5.1.9, paragraph 6.2.3, paragraph 7.1.3, paragraph 8.2.1 and paragraph 9.1.6) We repeat them here:

- Burner: RCA type, built by Pagny laboratories. There is a suction nozzle above the positive electrode with injection of compressed air to the upper part of the nozzle:

  - Exhaust flow: 150 m3/per hour
  - Flow of compressed air at 2 kg/cm2: 40 liters per minute.
  - Tungsten cathode of the RCA type: water cooled
  - Inclination of the cathode: 70°
  - Argon flow: 7 liters per minute

- Positive contacts are water cooled:

  - Speed of rotation of the positive: 11 rpm.
  - Protrusion: 12.7 mm.

- Operating values for the test:

  - Intensity: 400 amperes
  - Impact : 0
  - Arc gap : 20 mm.

Remark - The definition of impact point was given in Report No. 2, paragraphs 2.3.8 to 2.4.1.

- The striking of the arc is made by setting a metallic wire between the extremities of the cathode and the positive electrode, before applying the voltage.

- MEASUREMENTS MADE DURING THE BURNING

10.73 When we test the burning of the positive electrodes, we record:

- the arc voltage, expressed in volts, recorded during the test made at the normal current of 400 amps. (Report No. 3, paragraph 3.2.7).

- the burning rate of the positive electrode, expressed in mm/hour (Report No. 3 paragraph 3.2.8). It is measured for each burning test.

- the dimensional characteristics of the crater after burning, expressed in mm. These characteristics are: the diameter and the crater depth (Report No. 3, paragraph 3.2.9)

- the scalloping index of the crater, measured on the lateral projection of the arc (Report No. 3, paragraph 3.3.0)

- the pitting index, determined after the burning test by counting the number of pittings produced on a 120 mm diam. pyrex disc situated 120 mm in front of the positive electrode crater, centered on the axis of the electrode and in a perpendicular plane.

- the variations of the amperage and voltage recorded during the test.

C - MEASUREMENT OF RADIANCE

10.74 In order to determine the value of the radiance of the crater of the positive electrode, we make an enlarged image of the crater with a lens of small aperture. The area of the enlarged image of the crater is explored with a photo-electric cell. The value of the response of the cell allows us to compute the level of radiance of the corresponding point of the crater. The variations of the response of the cell during its travelling is recorded.

10.75 The stability of the total energetic emission is evaluated by placing a silicon cell in the axis of the positive electrode, without any lens. The output of the silicon cell is recorded.

D - DISTRIBUTION OF THE SPECTRAL RADIANCE

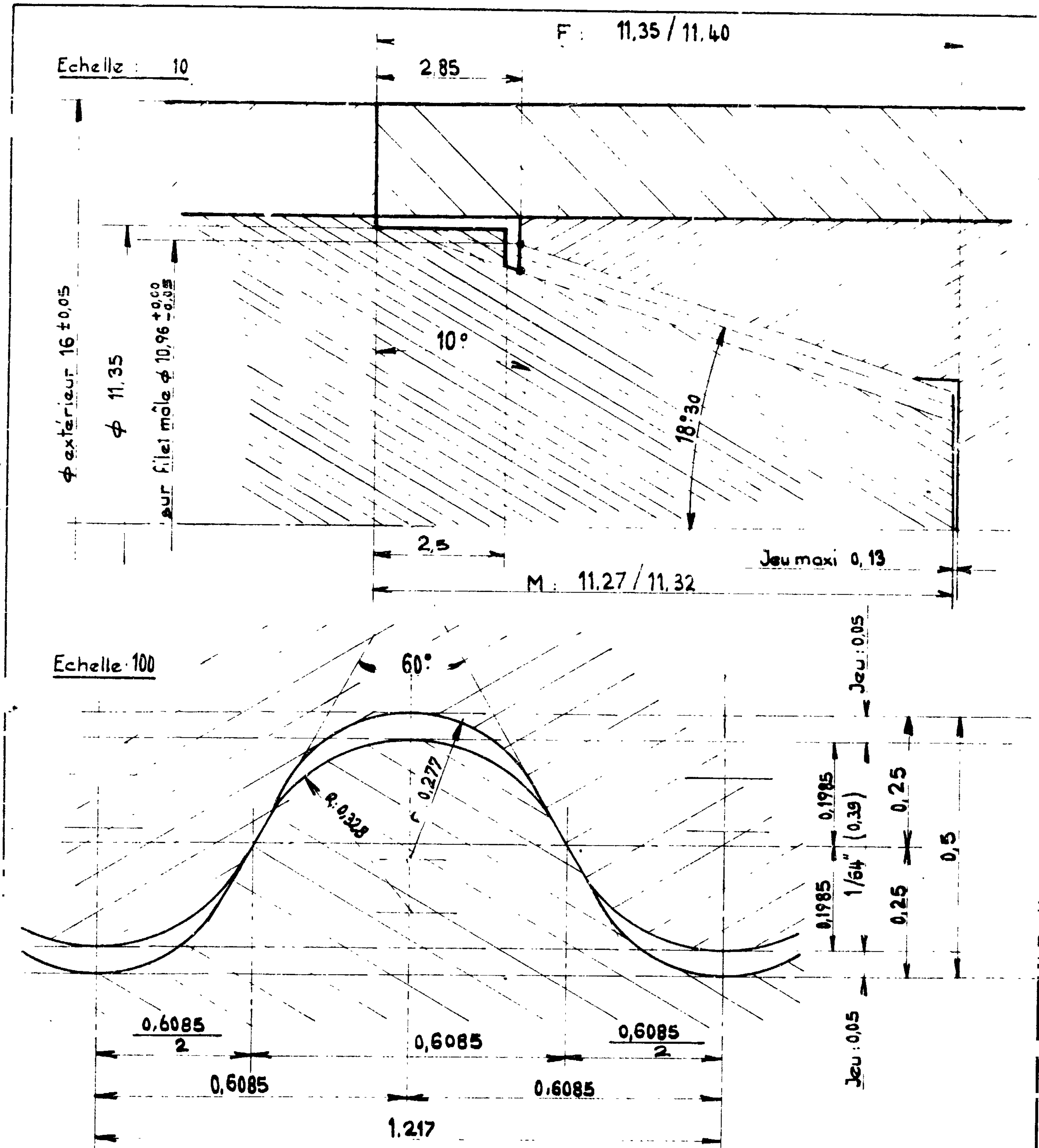
10.76 The study of the distribution of the spectral radiance is made with a spectrophotometer able to record wave lengths from0.40 to 0.72 microns and with a quartz prism spectrograph for the wave lengths from 0.22 to 0.50 microns.

The previous calibration of the apparatuses was made following the method indicated in Report No. 3, Chapter V, paragraphs 3.5.5 to 3.7.5 .

X - RESULTS OBTAINED WITH THE NEW ELECTRODES

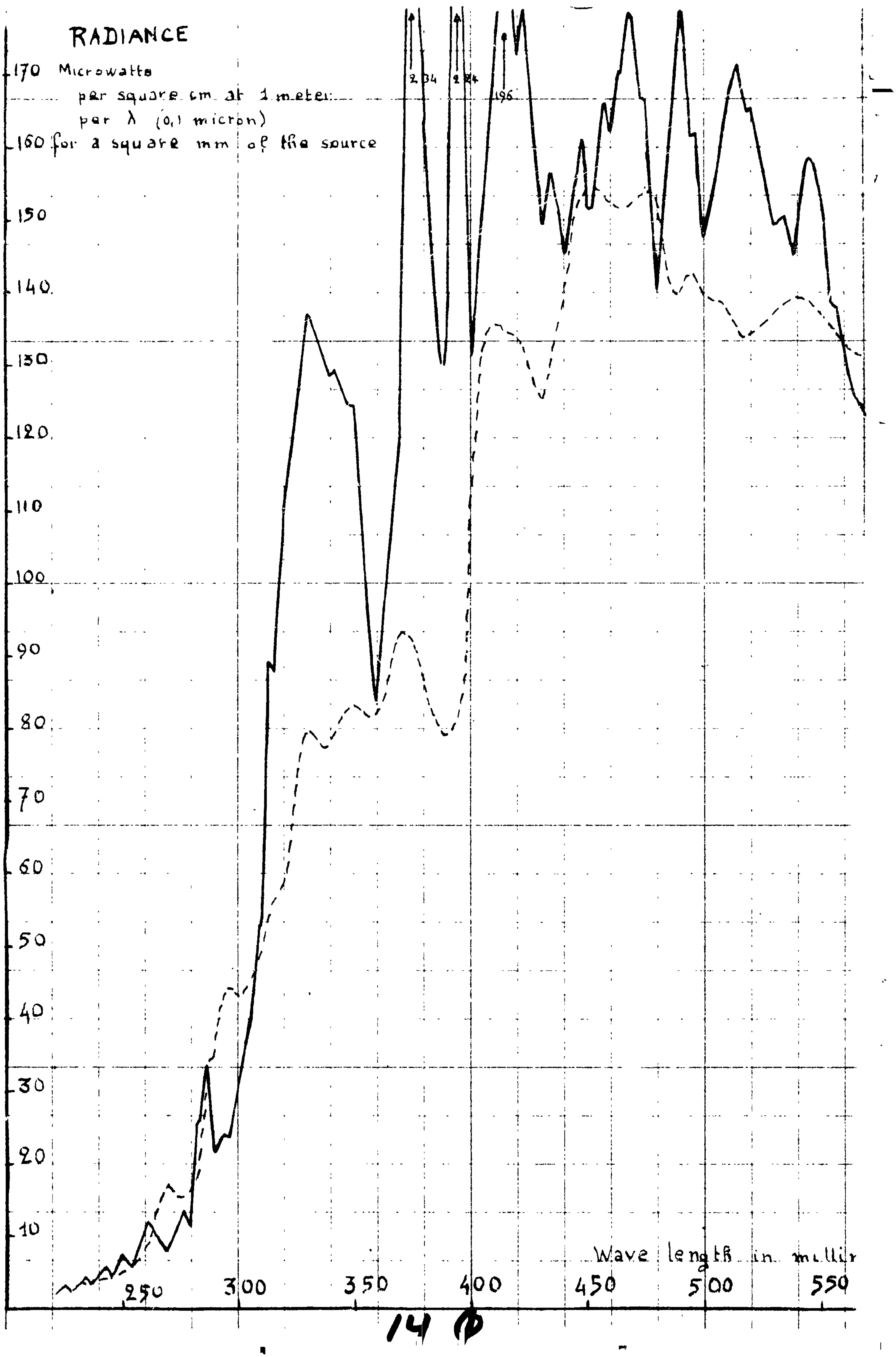
10.77 The spectral radiance distribution curves for the 16 mm diameter positive electrodos with shell 8848 and core 356 were established in Report No. 9 (paragraphs 9.9.4 to 9.9.6 - Figure No. 14). A copy of the curve is attached to this report.

10.78 In addition, attached to this report are the radiance distribution curves of the crater also recorded for these same electrodes. (Please see Report No. 9 paragraphs 9.9.7 and 9.9.8 - figures No. 15, 16 and 17).



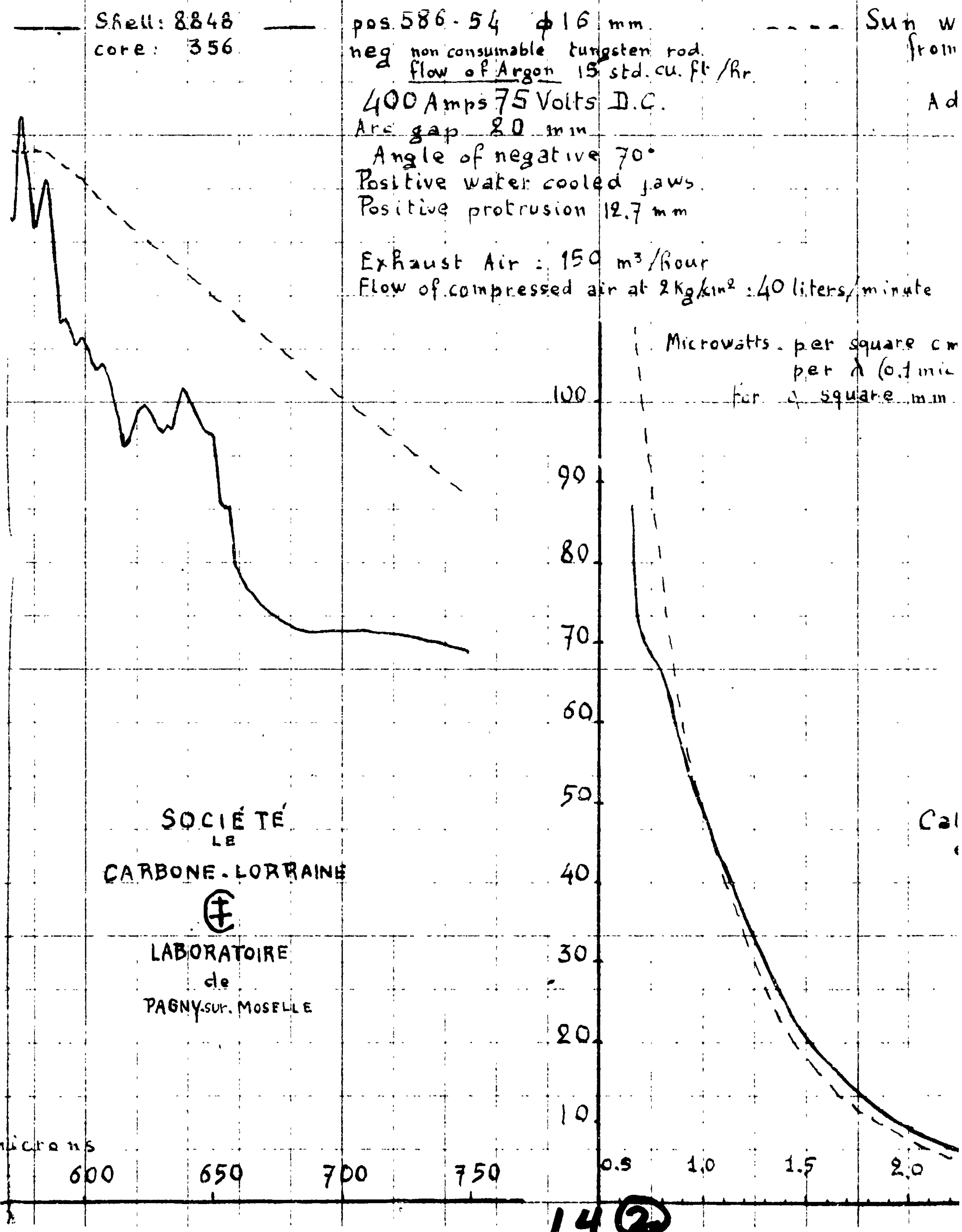
Nota: Pas réel suivant axe longitudinal de la pièce : 1/22" soit 1,154.
22 filets au Pouce. Cône 37°

Société le **CARBONE LORRAINE.** *22 Filets au Pouce.*	N° 1008
Echelle: / *Dessiné par:* AB / *Approuvé par:*	*Le : 5.05.196?*



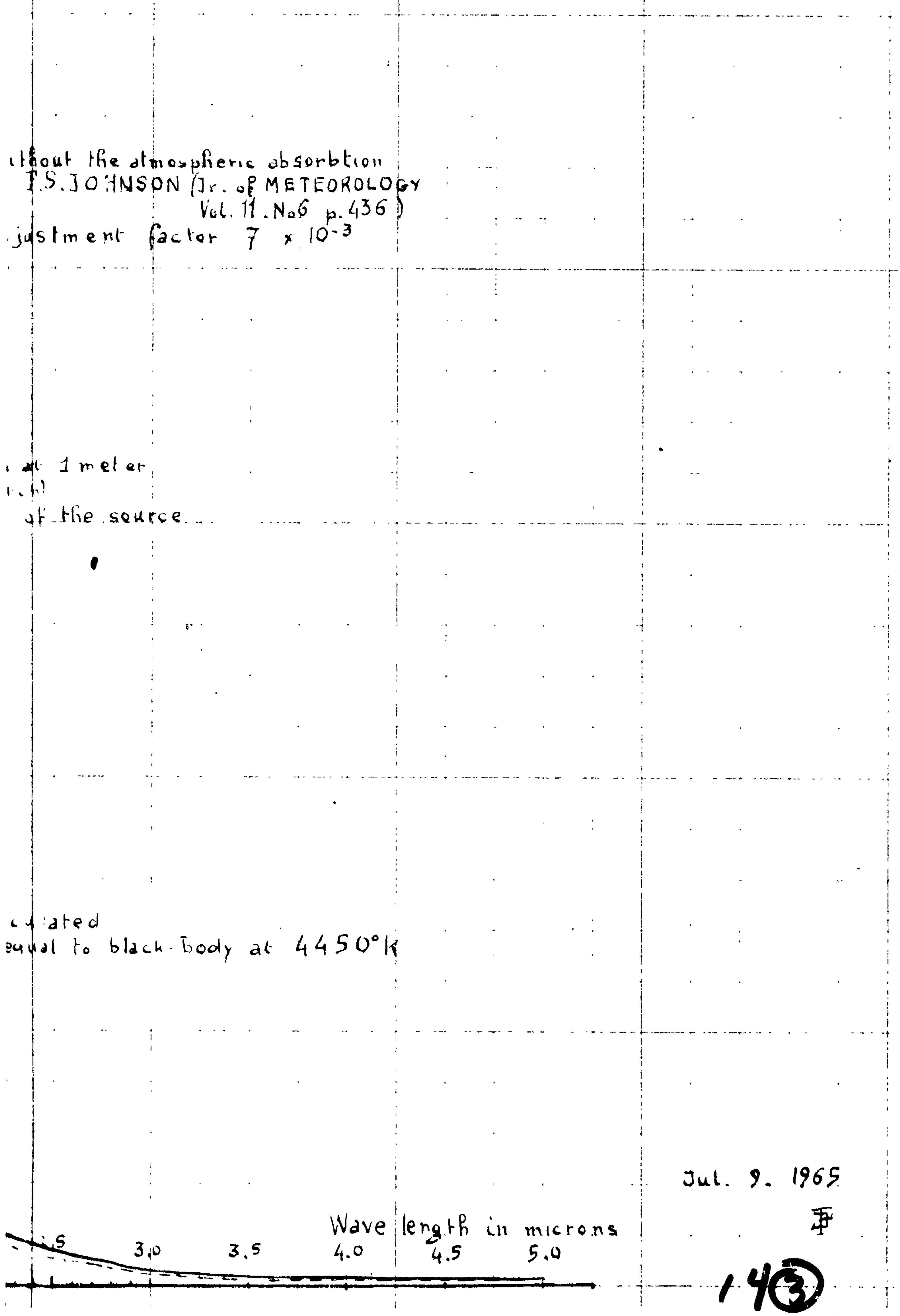
RADIANCE
Microwatts
per square cm at 1 meter
per λ (0,1 micron)
for a square mm of the source
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
234
224
196
Wave length in millir
250
300
350
400
450
500
550

SPECTRAL ENERGY DISTRIBUTION



REPORT No 9

Fig 14



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REPORT No 9 — Fig. 15

RADIANCE

Front view of crater

Shell : 8848
Core : 356

pos. 586-54 ϕ 16 mm
neg. non consumable tungsten rod
flow of Argon 15 std. cu. ft/hr.
380 Amps 73 Volts D.C.
Arc gap 20 mm
Angle of negative 70°
Positive water cooled jaws
Positive protrusion 12.7 mm
- Exhaust air : 150 m³/hour
- Flow of compressed air at 2 kg/cm² 40 litres/minute

Radiance values in microwatts per square cm at 1 meter per 1 square mm of the source

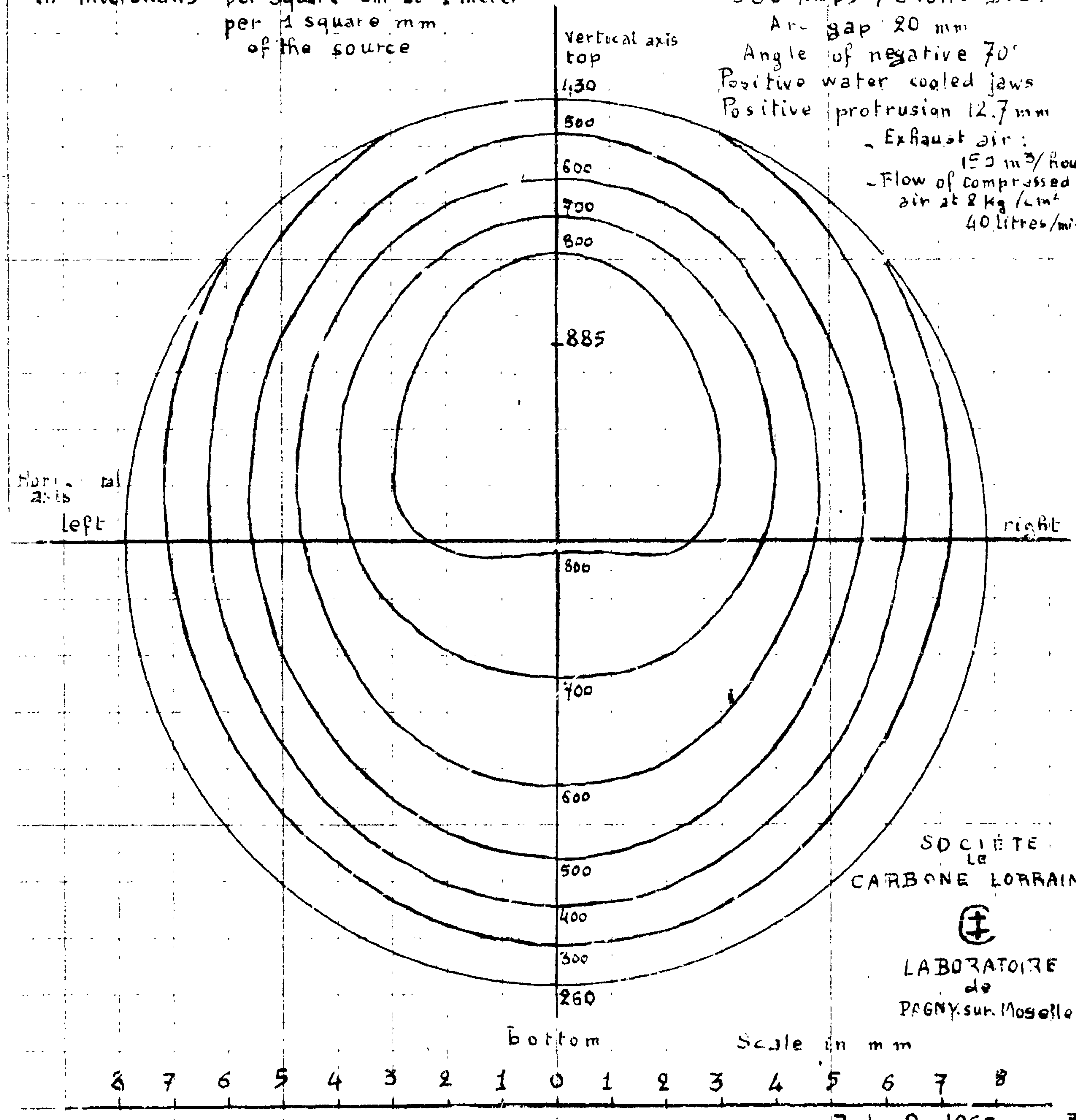

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Fig 16

RADIANCE

Front view of crater

Shell : 8848
Core : 356

pos. 586-54 ϕ 16 mm
neg. non consumable tungsten rod
flow of Argon 15 std. cu. ft / hr
400 Amps 75 Volts D.C.
Arc gap 20 mm
Angle of negative 70°
Positive water cooled jaws
Positive protrusion 12.7 mm
- Exhaust air : 150 m³/hour
- Flow of compressed air at 2 Kg/cm² : 40 litres/minute

Radiance values
in microwatts per square cm at 1 meter per 1 square mm of the source

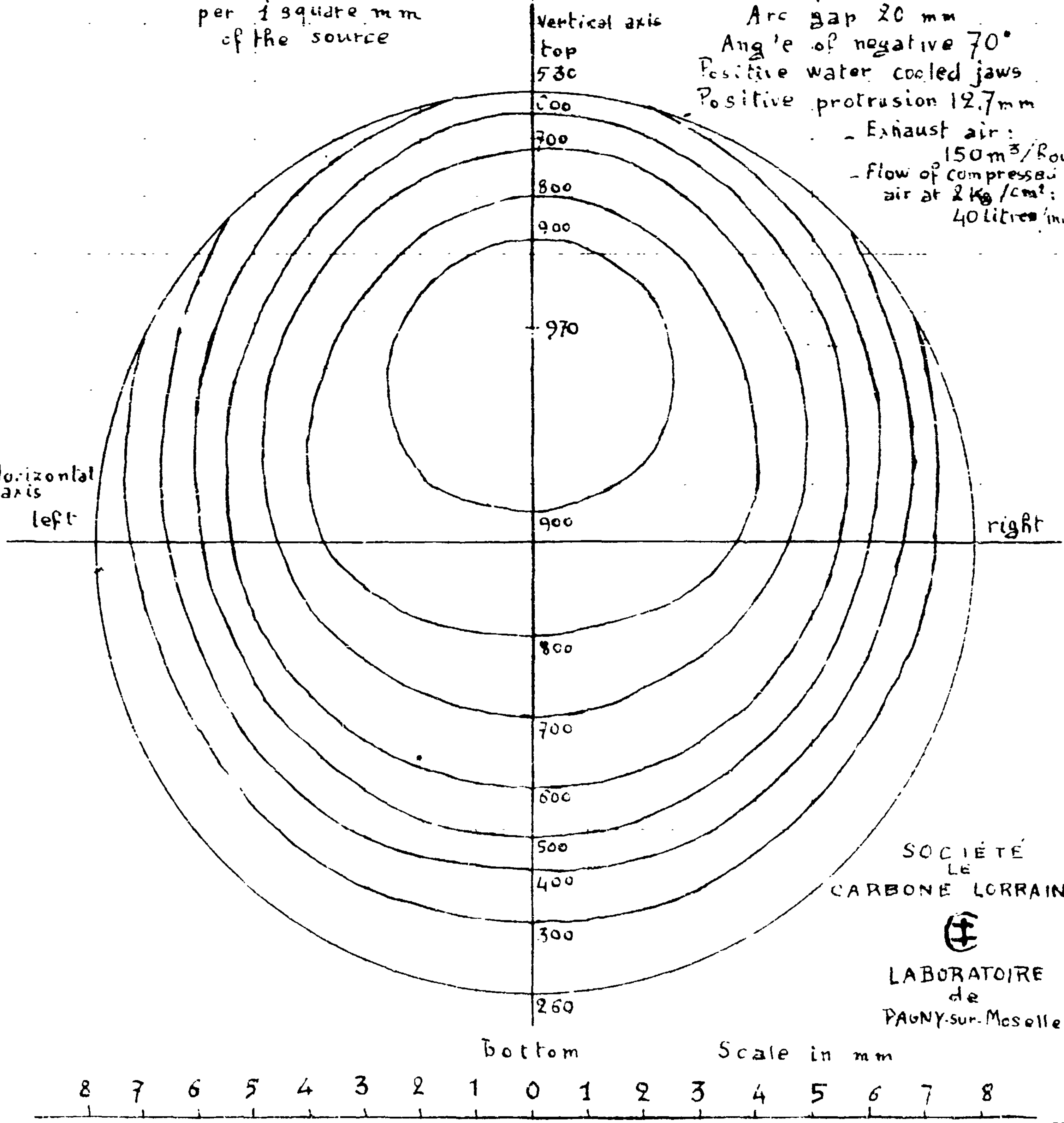

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Fig 17

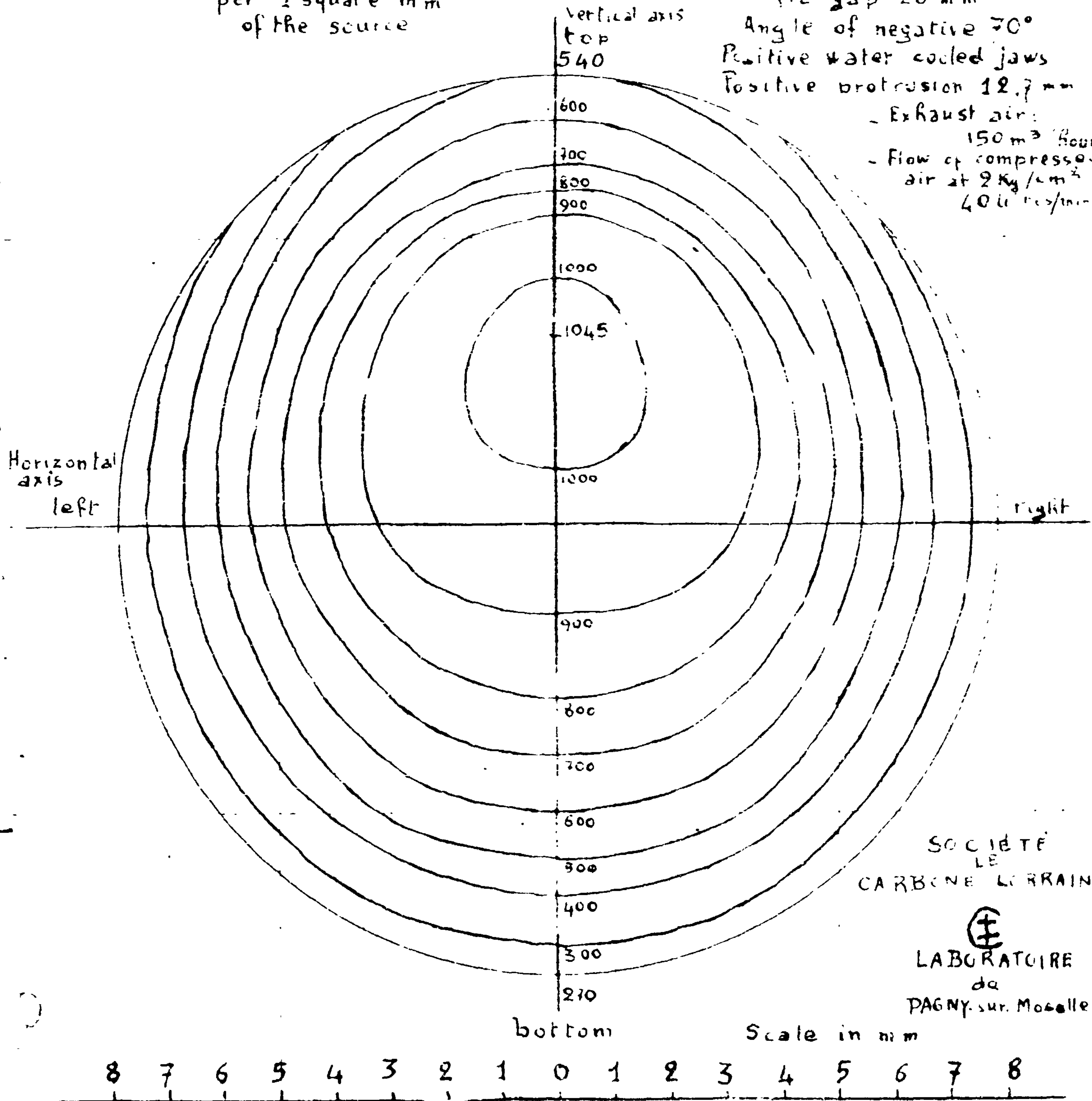
RADIANCE

Front view of crater

Shell. 8848
Core. 350

pos. 780-54 ϕ 25 mm
neg non consumable tungsten rod
flow of Argon 15 std. cu. ft./hr
420 Amps 78.5 Volts D.C.
Arc gap 20 mm
Angle of negative 70°
Positive water cooled jaws
Positive protrusion 12.7 mm
- Exhaust air: 150 m³/hour
- Flow of compressed air at 2 Kg/cm² 40 litres/minute

Radiance values in microwatts per square cm at 1 meter per 1 square mm of the source



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